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NASA CR-167863

COMPARATIVE ANALYSIS OF OPERATIONAL FORECASTS VS ACTUAL WEATHER CONDITIONS IN AIRLINE FLIGHT PLANNING

VOLUME II

PRC SPEAS
DIVISION OF PRC PLANNING AND ECONOMICS, INCORPORATED

PREPARED FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Project Manager, Robert Steinberg, Aircraft Propulsion Division, NASA Lewis Research Center, Cleveland, Ohio 44135

16. Abstract

A study was conducted on the impact of more timely and accurate weather data on airline flight planning with the emphasis on fuel savings. This volume of the report discusses the results of Task II of the four major tasks included in the study. Task II compared various categories of flight plans and flight tracking data produced by a simulation system developed for the Federal Aviation Administration by SRI International. (Flight tracking data simulate actual flight tracks of all aircraft operating at a given time and provide for rerouting of flights as necessary to resolve traffic conflicts.) The comparisons of flight plans on the forecast to flight plans on the verifying analysis confirmed Task I findings that wind speeds are generally underestimated. Comparisons involving flight tracking data indicated that actual fuel burn was always higher than planned, in either direction, and even when the same weather data set was used. Since the flight tracking model output resulted in more diversions than is known to be the case, it was concluded that there is an error in the flight tracking algorithm.

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1. INTRODUCTION

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PRC Speas, assisted by David R. Bornemann Associates, Inc. has conducted analyses of flight plan data for the National Aeronautics and Space Administration - Lewis Research Center under Contract #NAS3-22748.

The objective of these analyses was to assess the potential improvements in fuel savings which may be possible from improved meteorological data. Flight plans calculated from prescribed input parameters and meteorological data sets are used as quantitative indicators of differences in fuel burn and other relevant parameters. Flight plan data were provided through the cooperation of two airlines which will be referred to as "BLUE Airlines" and "RED Airlines" throughout this report in order to maintain anonymity.

The work program under this contract was divided into four tasks. This volume of the final report presents the findings of Task II which involved comparisons of winds and temperatures from flight plans based on operational forecasts or the verifying analyses with flight tracking based on forecasts or verifying analyses.

Subsequent sections of this volume describe the analysis methodology and results for Task II.

2. SUMMARY AND KEY FINDINGS

****

In Task II, comparisons were conducted between various categories of flight plans and flight tracking data that were produced by a simulation system developed at SRI International for the Federal Aviation Administration. Based upon a given set of weather data, which were provided by NASA and consisted of National Weather Service operational forecasts and the verifying analyses valid at the time of the forecasts, the system produced flight plans and flight tracking data. Flight tracking data simulate the actual flight tracks of all aircraft operating on a given weather data set and provide such features as the rerouting of some flights as necessary to resolve ATC conflicts.

Key findings were:

- When the SRI model was used to compare flight plans based on the forecast to flight plans based on the verifying analysis the data were consistent with and confirmed the Task I findings that wind speeds are generally underestimated and that fuel savings of 364 kg were possible for eastbound B747s on existing operational North Atlantic routes if the forecasts were equal to the verifying analysis.
- Comparisons involving flight tracking data found that actual fuel burn and flight times were always higher than planned, in either direction, and even when the same weather data set was used. This suggests that either there is an error in the flight tracking algorithm or that a penalty is incurred due to traffic congestion and resolution of ATC system conflicts in addition to the penalty incurred from inaccurate weather forecasts. Since the flight tracking model output resulted in more diversions than is known to be the case, it was concluded that there is an error in the flight tracking algorithm.

A summary of the other findings follows.

Four categories of data were provided to PRC Speas. These were:

(1) Flight plans based on operational forecast;

(2) Flight tracking based on the flight plans in (1) but using the verifying analysis valid at the time of the forecast;

(3) Flight plans based on the verifying analysis;

(4) Flight tracking based on the flight plans in (3) using the verifying analysis.

Using computer programs developed for this purpose, comparisons were made of differences in fuel burn, flight time, air miles, ground miles and the ratio of air miles to ground miles between the following flight plan and flight tracking categories:

Case 1 - Group 1 and Group 2

Case 2 - Group 1 and Group 3

Case 3 - Group 2 and Group 4

Case 4 - Group 3 and Group 4

Case 5 - Groups 1 and 3 with the actual airline flight plans from Task I

Comparisons were made for entire flights and for flight segments and were presented by direction of flight, region and by aircraft type groups such as B747s, DC10/L1011s, or B707/DC8s. Only the data for the B747 group are discussed in this summary section for ease in making comparisons with the findings of the other tasks. Results for the other aircraft types are presented in Section 4.

All of the weather data used in Task II were from either an operational NWS forecast (the Seven Level Primitive Equation Model) or from the verifying analysis valid at the time of the forecast (the Flattery Analysis). Although this verifying analysis is referred to as the "actual analysis" or the "actual" throughout this report, it should be understood that it is the actual weather as represented by the Flattery analysis model and is not necessarily the same as the actual weather observed by aircraft on that day.

2.1 CASE 1 FINDINGS

The first set of comparison data were developed by subtracting the flight tracking values based on the actual weather from the flight plan values developed on the forecast weather. The conditions in this case were similar to those in Case 1 of Task I in that the comparison measured potential fuel savings that could result if the weather forecast were equal to the verifying analysis. Only the model, or source of the flight plans, was different and the actual effect of ATC diversions was included.

The numbers of B747 flight plan comparisons in the sample and the average differences in fuel burn were:

	Sample Size	Burn Difference
Eastbound North Atlantic	167	-775 kg
Eastbound Polar	36	-810 kg
Westbound North Atlantic	235	-1278 kg
Westbound Polar	39	-451 kg

The negative values eastbound are contrary to the Task I findings and would imply that wind speeds are always overestimated, or that the flight tracking fuel burn is always higher because of ATC diversions.

For westbound flights these findings are consistent with the Task I results but they are contrary to the eastbound results and imply that aircraft always burn more than flight plan regardless of whether they are flying against or with a wind forecast error. One must conclude that the differences are not entirely weather related and must be greatly influenced by the conflict resolution algorithm of the flight tracking model.

2.2 CASE 2 FINDINGS

In the second case flight plans on the forecast weather were compared to flight plans on the verifying analysis. Except for the use of a

different flight planning model as the data source and except for the fact that new NAT tracks were selected on the verifying analysis, and thus routings could be different, this analysis was also similar to Case 1 of Task I.

The numbers of B747 flights compared and the average fuel burn differences for Case 2 were:

	Sample Size	Burn Difference
Eastbound North Atlantic	159	374 kg
Eastbound Polar	33	318 kg
Westbound North Atlantic	154	-237 kg
Westbound Polar	24	-420 kg

The positive differences eastbound and negative differences westbound were consistent with and confirmed the Task I conclusion that wind speeds were normally underestimated, and indicate that negative data sets in Task II Case 1 were probably the result of the flight tracking algorithm.

2.3 CASE 3 FINDINGS

Case 3 comparisons were developed by subtracting the times, burns and other parameters on the flight tracking data from Group 4, based on the verifying analysis, from the corresponding Group 2 flight tracking data which were also based on the verifying analysis but used flight plan inputs based on the forecast.

Since the same weather data were used in each case this comparison was a measure of the potential fuel savings (or penalty) that could result from improvements in the flight plan or track inputs to the flight tracking simulator.

The findings for B747 comparisons in Case 3 were:

	Sample Size	Burn Difference
Eastbound North Atlantic	159	273 kg
Eastbound Polar	33	96 kg
Westbound North Atlantic	154	243 kg
Westbound Polar	24	-79 kg

Positive values, both eastbound and westbound, suggest that fuel burn penalty from the ATC system is less when an improved forecast is used in flight planning or that errors were introduced by the flight tracking algorithm.

2.4 CASE 4 FINDINGS

Case 4 compared data from flight plans based on the verifying analysis to flight tracking data developed from the same verifying analysis.

Since the same weather was used, differences found between these two groups of plans were unrelated to weather but represented a measurement of the potential effect of improved NAT track selection and the conflict resolution simulations of the flight tracking model.

The findings for the B747 comparisons in Case 4 were:

	Sample Size	Burn Difference
Eastbound North Atlantic	160	-927 kg
Eastbound Polar	33	-1034 kg
Westbound North Atlantic	154	-599 kg
Westbound Polar	24	-76 kg

The negative differences in both directions suggest that actual flight times, fuel burns and air miles are always greater than planned even when the plans were based on the verifying analysis, and that these penalties are the result of conflict resolution and traffic congestion in the ATC system or in the flight tracking model.

2.5 CASE 5 FINDINGS

The objective of the final comparison in Task II was to determine the flight parameter differences between the flight plans developed by the SRI model for this task and the corresponding actual airline flight plans from Task III. However, since takeoff weights, flight levels and routings were quite different, average burn differences of more than 10,000 kg per flight were found. Since these variables could not be controlled, it would be difficult to attribute the differences to any particular cause and these data were judged to be of relatively little value.

3. ANALYSIS METHODOLOGY

****

The objectives of Task II required that comparisons be made between categories of flight plans and flight tracking, similar to the requirements of Task I. Four categories of data were provided. These were:

(1) Flight plans based on an operational forecast;

(2) Flight tracking based on the flight plans in (1) but using the verifying analysis valid at the time of the forecast;

(3) Flight plans based on the verifying analysis;

(4) Flight tracking based on the flight plans in (3) using the verifying analysis.

(Flight tracking data are produced by a simulation system developed at SRI International for the Federal Aviation Administration. The system is similar to airline flight planning systems such as the BLUE Airlines system in that it calculates flight plans based upon given weather data, aircraft performance and routing data. However, it also produces the flight tracking data which simulate the actual flight tracks of many aircraft on a given weather data set and provide such features as rerouting of some flights to resolve ATC conflicts.)

In Task II comparisons were made of fuel burn, flight time and the ratio of air miles to ground miles between categories 1 and 2; 1 and 3; 2 and

4; 3 and 4; and between 1 and 3 and the actual airline flight plans, where possible.

These comparisons are quite similar and parallel to those made in Task I. The same weather data sets were provided to SRI that were provided to the RED and BLUE airlines. The differences in Task II are:

- Flight plans and flight tracking are provided for many airlines rather than just RED and BLUE;
- Different North Atlantic Organized Tracks, developed manually using the verifying weather analyses are used for group (3) and (4) flight plans and flight tracking on some days;
- Aircraft performance data, route data, and in fact, the entire algorithm are the same for all flights, eliminating discrepancies resulting from differences between the RED and BLUE systems.

Given these similarities between the methodologies of Tasks I and II, Task II might also be considered a measure of the effect of differences between airline flight planning systems. However, the principal objective was still to measure fuel burn differences between flight plans based on the forecast and on the verifying analysis, but using a different system as the baseline. The flight tracking data also provided a measure of the potential for reduction of flight plan fuel burn through the improved procedure in laying-out the organized tracks using more accurate weather data.

3.1 DATA REDUCTION

As might be expected from the above discussion, the analysis procedure was quite similar to that employed in Task I. In fact, if one considered the task to be one of comparing "black boxes" of weather data to each other it doesn't really matter whether they are called flight tracking or flight plans, and the procedure is then identical to the Task I procedure.

In Task II the format of the input data was standardized and the same for all airlines and flight plan categories. These data, provided on magnetic tape, were scanned by computer programs developed by Bornemann Associates and work files were created to store pertinent data for further analysis. These files contained data similar to those saved in Task I, such as, origin, destination, airline, aircraft and region of the world. (All of the plans in this task were for Atlantic Ocean crossings, either Polar, North Atlantic, Mid-Atlantic or Caribbean.)

In this task almost all of the required data were printed directly on the flight plans or flight tracking and it was not necessary to derive data such as the wind being derived from the wind correction angle on the BLUE flight plans in Tasks I and III.

Comparisons were made for entire routes and by segments and were presented by direction of flight, region, and by aircraft type groups. The aircraft type groupings used were:

- B747
- DC10 and L1011
- B707 and DC8
- B727
- Military Aircraft

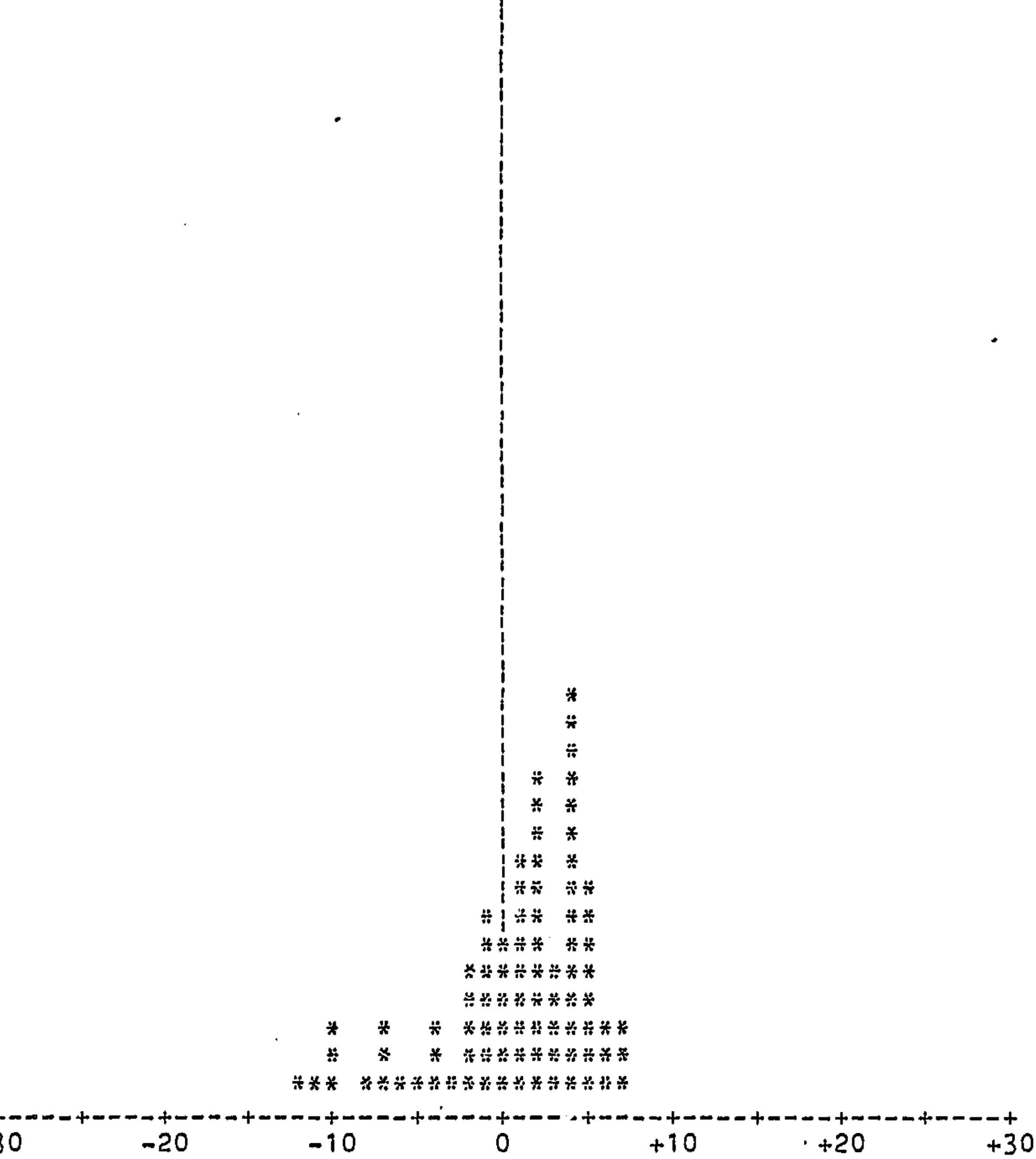
Figure 3-1 is a sample of the output format for the Task II results. A similar figure was produced for each category of comparison; eastbound and westbound; for each equipment group; and for each region - Polar, North Atlantic, Mid-Atlantic and Caribbean.

The value identified as the "Mean" under the histogram in Figure 3-1 is the mean of the algebraic differences between the data from the plan in the first group and the second group. In the figure, for example, it is the time on the Plan on Operational Weather MINUS the time on the Flight Tracking. Thus, negative values indicate that, in this example, the time on flight tracking was longer than the time on the operational plan.

Similarly, the value identified as "Mean (Absolute Dif.)" is the average of the absolute values of the differences between the two groups. The variance, standard deviation and 90 percent confidence limits refer to the data for the "Mean" and not to the "Mean (Absolute Dif.)".

Figure 3-1

SAMPLE OUTPUT



NUMBER OF OCCURRENCES BY DIFFERENCE

)ifference in Minutes

on Operational Weather MINUS Flight Tracking

```
MEAN                   =  .838323353
VARIANCE               =  17.045717
MEAN (ABSOLUTE DIF.)=     3.38922156
STANDARD DEVIATION     =  4.1286459
90% CONFIDENCE LIMITS          -5.95329915    TO    7.62994586
TOTAL OCCURRENCES      =  167
```

1ENT: B747 DIRECTION: Eastbound REGION: North Atlantic

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Source: PRC Speas Analysis of Flight Plans and Flight Tracking Data.

4. FINDINGS

****

The computer output results of the Task II analyses have been provided to NASA separately, in hard copy and on magnetic tape. They represent the findings of the analyses of all the flight plan and flight tracking data that were provided.

Although all of the Task II data come from just five runs (three westbound and two eastbound) from three days in 1979, the data are too voluminous to include in this report. The findings for each group of comparisons will be summarized, however, and discussed in detail along with comments on their practical significance.

4.1 FLIGHT PLANS ON THE FORECAST AND FLIGHT TRACKING ON THE ANALYSIS

The first group of comparisons was between flight plans based on the operational forecast and flight tracking based on the verifying analysis. These were comparisons of Group 1 vs. Group 2 data.

The conditions in this case were quite similar to the conditions in Case 1 of Task I. In Task I weights, routes and flight levels were held constant to the extent possible so that the differences in the two plans measured the differences, or errors, in the forecast. Here, the flight tracking simulates what the aircraft actually did under the actual

weather conditions so that weights, flight level and even routes may be different.

It was expected that the findings in this case should be comparable to the Task I findings. They should show the potential fuel savings that would result if the forecast were equal to the verifying analysis. These savings, or penalties, are adjusted to account for changes in the actual routing due to ATC requirements or more favorable conditions.

Figures 4-1 and 4-2 summarize the findings for Case 1 for entire routes. Figures 4-3 and 4-4 present the findings for route segments.

Figure 4-1 presents the results for eastbound flights by region and by aircraft type groups. A total of 672 flights were included in the comparison. Average burn differences between the flight plan and the flight tracking ranged from -141 kg for B707 and DC8 North Atlantic flights to -810 kg for B747 Polar flights. Time differences ranged from 1.6 minutes to -4.4 minutes.

These findings were inconsistent with the Task I results. Eastbound Case 1 flights in Task I all showed positive differences for burn and time leading to the conclusion that wind speeds were underforecast. In Task II the burn differences are negative while the time differences are positive, except in the Caribbean and Middle Atlantic regions. Although

Figure 4-1

TASK II RESULTS
FLIGHT PLANS ON FORECAST MINUS FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 1)
EASTBOUND (Entire Flights)

B747 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn (kg)	167	-775	24378	1051	-2505 to 955
	Time (mins)		0.8	17.0	4.1	-6.0 to 7.6
	Ratio		.0017	.0437	.0066	-.0092 to .0126
	Air Mi (nm)		-3	1062	33	-57 to 50
	Grnd Mi (nm)		-10	748	27	-55 to 35
Polar	Burn	36	-810	36910	1294	-2939 to 1318
	Time		1.6	14.7	3.8	-4.8 to 7.9
	Ratio		.0023	.0375	.0061	-.0078 to .0123
	Air Mi		12	716	27	-32 to 56
	Grnd Mi		0	0	0	0

DC10, L1011 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	57	-296	7482	583	-1255 to 662
	Time		0.5	21.3	4.6	-7.0 to 8.1
	Ratio		.0027	.0428	.0065	-.0080 to .0135
	Air Mi		-3	1108	33	-58 to 52
	Grnd Mi		-12	850	29	-60 to 36
Caribbean	Burn	37	-591	11600	725	-1784 to 602
	Time		-2.1	37.1	6.1	-12.1 to 7.9
	Ratio		-.0062	.0260	.0051	-.0146 to .0022
	Air Mi		-9	58	8	-22 to 3
	Grnd Mi		0	0	0	0

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	195	-141	5236	487	-942 to 661
	Time		1.0	22.7	4.8	-6.9 to 8.8
	Ratio		.0017	.0642	.0080	-.0115 to .0148
	Air Mi		1	900	30	-48 to 50
	Grnd Mi		-5	540	23	-43 to 33

Figure 4-1 (Continued)

B707, DC8 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Middle Atlantic	Burn (kg)	39	-377	9726	664	-1470 to 716
	Time (mins)		-1.2	63.1	7.9	-14.3 to 11.9
	Ratio		-.0018	.0555	.0074	-.0140 to .0105
	Air Mi (nm)		-1	381	20	-33 to 31
	Grnd Mi (nm)		0	0	0	0
Caribbean	Burn	89	-469	11570	725	-1662 to 725
	Time		-4.4	93.2	5.2	-20.1 to 11.5
	Ratio		-.0062	.0512	.0072	-.0179 to .0056
	Air Mi		-11	158	13	-32 to 9
	Grnd Mi		0	0	0	0

B727 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Caribbean	Burn	30	-145	2176	314	-662 to 372
	Time		-2.2	30.1	5.5	-11.2 to 6.9
	Ratio		-.0034	.1051	.0103	-.0203 to .0135
	Air Mi		-6	162	13	-27 to 15
	Grnd Mi		0	0	0	0

MILITARY AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	22	62	177	284	-405 to 528
	Time		0.9	9.3	3.0	-4.2 to 5.9
	Ratio		.0001	.0520	.0072	-.0117 to .0120
	Air Mi		2	522	23	-36 to 40
	Grnd Mi		0	0	0	0

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-2

TASK II RESULTS
FLIGHT PLANS ON FORECAST MINUS FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 1)
WESTBOUND (Entire Flights)

B747 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn (kg)	235	-1278	20682	969	-2871 to 316
	Time (mins)		-2.0	28.7	5.4	-10.8 to 6.8
	Ratio		-.0080	.1620	.0127	-.0289 to .0129
	Air Mi (nm)		-26	1327	36	-86 to 34
	Grnd Mi (nm)		0	380	19	-32 to 32
Polar	Burn	39	-451	13423	780	-1735 to 833
	Time		-1.6	18.8	4.3	-8.7 to 5.6
	Ratio		-.0033	.0426	.0065	-.0140 to .0074
	Air Mi		-14	879	30	-63 to 34
	Grnd Mi		0	0	0	0

DC10, L1011 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	98	-781	13857	793	-2085 to 523
	Time		-2.9	28.9	5.4	-11.7 to 5.9
	Ratio		-.0077	.1463	.0121	-.0276 to .0122
	Air Mi		-29	1013	32	-81 to 24
	Grnd Mi		-3	478	22	-39 to 33
Caribbean	Burn	36	-224	6039	524	-1085 to 637
	Time		0.8	3.9	2.0	-2.4 to 4.1
	Ratio		.005	.0368	.0061	-.005 to .0150
	Air Mi		6	153	12	-14 to 27
	Grnd Mi		0	0	0	0

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	266	-436	5681	508	-1271 to 399
	Time		-2.5	24.4	4.9	-10.6 to 5.6
	Ratio		-.0083	.1367	.0117	-.0275 to .0109
	Air Mi		-25	1185	34	-82 to 32
	Grnd Mi		-1	443	21	-35 to 34

Figure 4-2 (Continued)

B707, DC8 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Middle Atlantic	Burn (kg)	52	-265	6136	528	-1133 to 603
	Time (mins)		-1.6	3.7	5.3	-10.3 to 7.1
	Ratio		-.0003	.0984	.0099	-.0166 to .0160
	Air Mi (nm)		-5	700	26	-48 to 39
	Grnd Mi (nm)		0	0	0	0
Caribbean	Burn	97	-82	3994	426	-783 to 618
	Time		1.4	9.3	3.0	-3.6 to 6.5
	Ratio		.0057	.0423	.0065	-.0050 to .0164
	Air Mi		11	123	11	-8 to 29
	Grnd Mi		0	0	0	0

B727 AIRCRAFT

Caribbean	Burn	24	-246	264	346	-815 to 324
	Time		-1	31.8	5.6	-10.3 to 8.3
	Ratio		.0004	.0693	.0083	-.0133 to .0141
	Air Mi		1	129	11	-17 to 20
	Grnd Mi		0	0	0	0

MILITARY AIRCRAFT

North Atlantic	Burn	42	-247	2491	336	-800 to 306
	Time		-4.0	19.3	4.4	-11.3 to 3.2
	Ratio		-.0077	.0878	.0094	-.0231 to .0077
	Air Mi		-21	959	31	-72 to 30
	Grnd Mi		0	0	0	0

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-3

TASK II RESULTS
FLIGHT PLANS ON FORECAST MINUS FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 1)
EASTBOUND (Flight Segments)

	NORTH ATLANTIC		POLAR		MIDDLE ATLANTIC		CARIBBEAN	
	Segments	Mean	Segments	Mean	Segments	Mean	Segments	Mean
B747 AIRCRAFT								
Burn (kg)	1092	-5	255	-28				
Time (mins)		0.2		0.2				
DC10, L1011 AIRCRAFT								
Burn (kg)	337	6					138	-18
Time (mins)		0.3						-0.4
B707, DC8 AIRCRAFT								
Burn (kg)	1502	2			157	-15	454	-20
Time (mins)		0.2				-0.1		-0.8
B727 AIRCRAFT								
Burn (kg)							181	-3
Time (mins)								-0.3
MILITARY AIRCRAFT								
Burn (kg)	160	5						
Time (mins)		0.1						

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-4

TASK II RESULTS
FLIGHT PLANS ON FORECAST MINUS FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 1)
WESTBOUND (Flight Segments)

	NORTH ATLANTIC		POLAR		MIDDLE ATLANTIC		CARIBBEAN	
	Segments	Mean	Segments	Mean	Segments	Mean	Segments	Mean
B747 AIRCRAFT								
Burn (kg)	1425	-61	234	-39				
Time (mins)		-0.2		-0.2				
DC10, L1011 AIRCRAFT								
Burn (kg)	687	-36					136	5
Time (mins)		-0.2						0.1
B707, DC8 AIRCRAFT								
Burn (kg)	2078	-28			237	-26	453	-3
Time (mins)		-0.3				-0.4		0.1
B727 AIRCRAFT								
Burn (kg)							103	-8
Time (mins)								-0.4
MILITARY AIRCRAFT								
Burn (kg)	293	-23						
Time (mins)		-0.3						

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

they are not large, or consistent by region and aircraft type, the differences in air miles and ground miles are also mostly negative.

The inconsistency with the Task I findings and the combined effect of negative air mile differences, negative fuel burn differences, and positive time differences suggests that the differences are not weather related at all. It is more likely that the differences shown here are partly the result of some feature in the flight tracking model, probably a tendency to keep the aircraft at lower flight levels than planned.

Figure 4-2 presents the corresponding westbound findings. The burn differences range from -82 kg for Caribbean B707 and DC8 flights to -1278 kg for B747 North Atlantic flights. Time differences range up to four minutes and are all negative except for Caribbean flights and for B707 Polar flights.

While these findings are consistent with Task I findings (negative differences westbound indicating underforecast wind speeds) they are not consistent with the Task II eastbound findings. They suggest that aircraft actually burn more than flight plan regardless of whether they are flying against or with a wind forecast error. One must conclude that the differences are not entirely weather related and must be greatly influenced by the the conflict resolution algorithm of the SRI flight tracking model.

The corresponding findings for flight segments for Case 1 are presented in Figures 4-3 and 4-4. Comparisons of these data to the statistics presented for flight totals show that the segment data are inconsistent and may be misleading.

One would expect that, on the average, the data representing the flight totals should be equal to the average segment values times the average number of segments per flight. However, this is not so. Comparing Figure 4-3 to Figure 4-1 shows that the flight total figures for burn difference are five to 25 times larger than would be expected from the sums of the segment values. In two cases even the sign is reversed. Positive differences were found for the segments while negative differences were found for the flight totals.

Closer inspection of the data revealed that the probable cause of this apparent inconsistency was the selective elimination of unmatched segments by the analysis program. For flight totals, the program only checked for a matching origin and destination before including that flight in the comparison. For flight segments, a match of flight level was also required.

If the suspicion mentioned earlier is true that the flight tracking model tended to keep aircraft at lower altitudes when diversion is necessary, then the analysis program's flight level check would tend to reject more segments where the flight tracking was at a lower altitude

than the flight plan. These rejected segments would have positive burn differences and result in the average burn difference being less negative or even positive.

In addition to this factor, it was noted that the SRI model permitted step climbs at any point in the flight whereas the analysis program only checked for a flight level match at the end of each segment. Thus, a large portion of many segments could have been flown at different flight levels and still be included in the statistics introducing a degree of distortion in the segment results while not affecting the flight totals data.

4.2 FLIGHT PLANS ON THE FORECAST AND ON THE VERIFYING ANALYSIS

Case 2 compared flight plans developed on the operational forecast to flight plans developed on the verifying analysis valid at the time of that forecast or Group 1 vs. Group 3 plans.

Again, the conditions in this case were quite similar to those in Case 1 of this task and to those in Case 1 of Task I. Flight plans on the forecast are being compared to flight plans on the verifying analysis but, in this case, the added variable resulting from flight tracking is eliminated. The plan on the actual was not subject to rerouting due to decisions from the flight tracking simulation. However, since a different set of ATC tracks was used on some days, it is possible that

the plan on the verifying analysis (the Group 3 plan) was on a different route.

Except for the possible routing difference just mentioned, one could say this analysis is identical to Case 1 of Task I except that here the SRI model is being used to calculate the flight plans rather than the RED or BLUE airline flight planning systems. One might say the SRI model is the "GREEN Airline" flight planning system.

Figures 4-5 and 4-6 present the Case 2 results for entire flights and Figures 4-7 and 4-8 present the corresponding findings for flight segments.

Figure 4-5 presents the results for eastbound flights by region and by aircraft type group. There were 586 eastbound flights included in this analysis. Average fuel burn differences ranged from -126 kg for Caribbean DC10/L1011 flights to 374 kg for North Atlantic B747 flights. Time differences ranged from -4.3 minutes for North Atlantic military flights to 2.3 minutes for North Atlantic DC10/L1011 flights.

Except for Caribbean flights, the burn differences for eastbound flights were positive indicating lower fuel burns on the verifying analysis, or in other words, underestimated wind speeds. Time differences were also positive for all North Atlantic, Polar and Middle Atlantic flights

Figure 4-5

FLIGHT PLANS ON FORECAST MINUS PLANS ON THE VERIFYING ANALYSIS (CASE 2)
EASTBOUND (Entire Flights)

B747 AIRCRAFT

		Flights	Mean	Vari- ance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn (kg)	159	374	9572	659	-710 to 1458
	Time (mins)		2.2	13.3	3.7	-3.8 to 8.2
	Ratio		.0052	.0549	.0074	-.007 to .0174
	Air Mi (nm)		10	738	27	-34 to 55
	Grnd Mi (nm)		-8	240	15	-33 to 18
Polar	Burn	33	318	15416	836	-1058 to 1693
	Time		1.7	12.0	3.5	-4.0 to 7.4
	Ratio		.0017	.0469	.0068	-.0095 to .013
	Air Mi		15	715	27	-29 to 59
	Grnd Mi		7	436	21	-27 to 42

DC10, L1011 AIRCRAFT

		Flights	Mean	Vari- ance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	53	292	6117	527	-574 to 1158
	Time		2.3	13.0	3.6	-3.6 to 8.3
	Ratio		.0049	.0562	.0075	-.0074 to .0172
	Air Mi		10	639	25	-31 to 52
	Grnd Mi		-7	71	8	-21 to 7
Caribbean	Burn	27	-126	179	90	-275 to 22
	Time		-1.0	0.5	0.7	-2.2 to 0.2
	Ratio		-.0051	.0178	.0042	-.0120 to .0018
	Air Mi		-8	38	6	-18 to 3
	Grnd Mi		0	0	0	0

B707, DC8 AIRCRAFT

		Flights	Mean	Vari- ance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	173	270	8956	637	-779 to 1318
	Time		2.1	32.8	5.7	-7.3 to 11.5
	Ratio		.004	.0887	.0094	-.0115 to .0195
	Air Mi		7	980	31	-45 to 58
	Grnd Mi		-7	503	22	-44 to 30

Figure 4-5 (Continued)

B707, DC8 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Middle Atlantic	Burn (kg)	33	55	1338	246	-350 to 461
	Time (mins)		0.8	8.2	2.9	-3.9 to 5.5
	Ratio		.0031	.0555	.0075	-.0092 to .0153
	Air Mi (nm)		3	458	21	-32 to 39
	Grnd Mi (nm)		-11	897	30	-60 to 38
Caribbean	Burn	66	-108	217	99	-272 to 54
	Time		-1.3	1.4	1.2	-3.3 to 0.6
	Ratio		-.0052	.0194	.0044	-.0125 to .0020
	Air Mi		-9	66	8	-23 to 4
	Grnd Mi		0	0	0	-1 to 1

B727 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Caribbean	Burn	22	-52	175	89	-198 to 95
	Time		-0.9	1.5	1.2	-2.9 to 1.1
	Ratio		-.0033	.0636	.008	-.0164 to .0098
	Air Mi		-6	106	10	-23 to 11
	Grnd Mi		0	0	0	0

MILITARY AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	20	277	13529	784	-1012 to 1566
	Time		-4.3	93.8	9.7	-11.7 to 20.2
	Ratio		.0035	.0697	.0084	-.0103 to .0172
	Air Mi		11	919	30	-39 to 61
	Grnd Mi		-2	197	14	-25 to 22

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-6

FLIGHT PLANS ON FORECAST MINUS PLANS ON THE VERIFYING ANALYSIS (CASE 2)
WESTBOUND (Entire Flights)

B747 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn (kg)	154	-237	13994	797	-1548 to 1074
	Time (mins)		-0.3	17.0	4.1	-7.1 to 6.5
	Ratio		-.0005	.1614	.0127	-.0214 to .0204
	Air Mi (nm)		-10	789	28	-56 to 36
	Grnd Mi (nm)		-7	1010	32	-59 to 46
Polar	Burn	24	-420	15541	840	-1801 to 961
	Time		-1.2	11.6	3.4	-6.8 to 4.4
	Ratio		-.0043	.0343	.0059	-.0140 to .0053
	Air Mi		-12	678	26	-55 to 30
	Grnd Mi		6	165	13	-15 to 27

DC10, L1011 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	65	-52	15088	828	-1413 to 1309
	Time		0.3	24.0	4.9	-7.7 to 8.4
	Ratio		-.0008	.1733	.0132	-.0224 to .0209
	Air Mi		-2	1639	40	-68 to 65
	Grnd Mi		-1	1270	36	-60 to 57
Caribbean	Burn	30	60	770	187	-247 to 368
	Time		0.4	2.0	1.4	-1.9 to 2.7
	Ratio		.0039	.0200	.0045	-.0035 to .01126
	Air Mi		5	95	10	-11 to 21
	Grnd Mi		-1	12	3	-6 to 5

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	178	27	13646	787	-1267 to 1321
	Time		0.2	30.5	5.5	-8.9 to 9.2
	Ratio		-.0016	.2444	.0156	-.0273 to .0241
	Air Mi		-5	1494	39	-68 to 59
	Grnd Mi		1	2006	45	-73 to 75

Figure 4-6 (Continued)

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
Middle Atlantic	Burn (kg)	39	-122	3321	388	-761 to 516
	Time (mins)		-0.6	13.4	3.7	-6.6 to 5.4
	Ratio		-.0009	.1210	.0110	-.0190 to .0172
	Air Mi (nm)		-4	723	27	-48 to 40
	Grnd Mi (nm)		4	437	21	-31 to 38
Caribbean	Burn	79	112	338	124	-92 to 316
	Time		1.0	1.8	1.3	-1.1 to 3.2
	Ratio		.0051	.0293	.0054	-.0038 to .0140
	Air Mi		9	80	9	-5 to 24
	Grnd Mi		0	7	3	-4 to 4

B727 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
Caribbean	Burn	20	14	196	94	-141 to 168
	Time		0.1	1.9	1.4	-2.2 to 2.4
	Ratio		.0018	.0516	.0072	-.0101 to .0136
	Air Mi		3	100	10	-14 to 19
	Grnd Mi		0	0	0	0

MILITARY AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	28	-120	2480	335	-672 to 432
	Time		-1.2	19.4	4.4	-8.5 to 6.0
	Ratio		-.0034	.1682	.0130	-.0248 to .0179
	Air Mi		-11	835	29	-58 to 37
	Grnd Mi		-3	1005	32	-55 to 49

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-7

TASK II RESULTS

FLIGHT PLANS ON FORECAST AND ON THE VERIFYING ANALYSIS (CASE 2)
EASTBOUND (Flight Segments)

	NORTH ATLANTIC		POLAR		MIDDLE ATLANTIC		CARIBBEAN	
	Segments	Mean	Segments	Mean	Segments	Mean	Segments	Mean
B747 AIRCRAFT								
Burn (kg)	463	106	145	374				
Time (mins)		0.1		0.3				
DC10, L1011 AIRCRAFT								
Burn (kg)	164	138					98	-194
Time (mins)		0.2						-0.3
B707, DC8 AIRCRAFT								
Burn (kg)	604	99			75	110	298	-124
Time (mins)		0.2				0		-0.3
B727 AIRCRAFT								
Burn (kg)							110	-36
Time (mins)								0
MILITARY AIRCRAFT								
Burn (kg)	51	-188						
Time (mins)		-0.1						

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-8

TASK II RESULTS

FLIGHT PLANS ON FORECAST AND ON THE VERIFYING ANALYSIS (CASE 2)
WESTBOUND (Flight Segments)

	NORTH ATLANTIC		POLAR		MIDDLE ATLANTIC		CARIBBEAN	
	Segments	Mean	Segments	Mean	Segments	Mean	Segments	Mean
B747 AIRCRAFT								
Burn (kg)	284	-147	69	-15				
Time (mins)		-0.1		0.1				
DC10, L1011 AIRCRAFT								
Burn (kg)	118	-117					107	140
Time (mins)		-0.1						0.2
B707, DC8 AIRCRAFT								
Burn (kg)	437	34			108	20	306	142
Time (mins)		6.9				0		0.2
B727 AIRCRAFT								
Burn (kg)							66	20
Time (mins)								-0.2
MILITARY AIRCRAFT								
Burn (kg)	49	113						
Time (mins)		0.3						

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

except for the military group which is also consistent with the Task I findings.

As was found with Africa flights in Task I, it is suspected that many of the Caribbean flights are actually more in the north or south direction. The eastbound or westbound groupings here are somewhat artificial and this may explain the inconsistencies in the Caribbean data.

The westbound findings by aircraft type group and region are presented in Figure 4-6. Data are included for 617 flights. Fuel burn differences ranged from 112 kg for Caribbean B707/DC8 flights to -420 kg for Polar B747 flights. Average time differences were relatively small, ranging from one minute for Caribbean B707/DC8 flights to -1.2 minutes for B747 Polar and North Atlantic military flights.

Again, with the exception of the Caribbean data, these findings were completely consistent with the previous results. Fuel burn differences were negative indicating underestimated wind speeds. Time differences and air miles were also negative or near zero.

Figures 4-7 and 4-8 present the results of the analysis by flight segments. As in the previous case and those that follow, the segment data are distorted somewhat by the rejection of segments with unmatched flight levels and no further comment is warranted.

4.3 FLIGHT TRACKING ON THE VERIFYING ANALYSIS

Case 3 analyzed differences between two different sets of flight tracking data. Flight tracking developed on the verifying analysis was compared to a second set of flight tracking data developed on the same weather data but based on input flight plans that were developed on the forecast.

Since the same weather data were used for each group the weather affected the analysis only indirectly and the differences that were found were the result of different solutions to the conflict resolution algorithm between the two sets of input flight plans - one based on the forecast and one based on the verifying analysis. While the flight tracking developed from the plans based on the forecast used the original or operational NAT tracks, new NAT tracks were sometimes selected for the flight tracking developed from the flight plans on the verifying analysis.

Therefore, it was expected that differences in this case would be the result of improvements (or penalties) caused by laying-out the ATC tracks on an improved forccast or from the ATC system's ability to reduce conflict resolution penalties through improved weather and flight plan inputs.

Results of the Case 3 analysis are presented in Figures 4-9 through 4-12. Figures 4-9 and 4-10 show the results for entire flights and Figures 4-11 and 4-12 present the results for flight segments.

Figure 4-9

TASK II RESULTS

FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 3)
EASTBOUND (Entire Flights)

B747 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn (kg)	159	273	25905	1084	-1511 to 2056
	Time (mins)		0.3	18.8	4.3	-6.8 to 7.5
	Ratio		.0029	.0297	.0055	-.0060 to .0119
	Air Mi (nm)		5	1007	32	-47 to 57
	Grnd Mi (nm)		-5	1205	35	-62 to 52
Polar	Burn	33	96	17691	896	-1377 to 1570
	Time		0	5.2	2.3	-3.7 to 3.8
	Ratio		-.0013	.0121	.0035	-.0070 to .0044
	Air Mi		1	124	11	-17 to 19
	Grnd Mi		7	436	21	-27 to 42

DC10, L1011 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	53	350	6515	544	-544 to 1245
	Time		1.0	18.8	4.3	-6.2 to 8.1
	Ratio		.0026	.0142	.0038	-.0036 to .0088
	Air Mi		9	955	31	-42 to 60
	Grnd Mi		-1	1056	32	-54 to 53
Caribbean	Burn	27	64	4797	466	-704 to 831
	Time		0.3	27	5.2	-8.3 to 8.8
	Ratio		0	.0003	.0005	-.0009 to .0009
	Air Mi		0	1	1	-1 to 1
	Grnd Mi		0	0	0	0

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	173	243	10349	685	-885 to 1370
	Time		0.9	47.9	6.9	-10.5 to 12.3
	Ratio		.0027	.0426	.0065	-.0080 to .0134
	Air Mi		3	1156	34	-53 to 59
	Grnd Mi		-4	1032	32	-57 to 49

Figure 4-9 (Continued)

B707, DC8 AIRCRAFT

		Flights	Mean	Vari- ance	Std. Dev.	90 Percent Confidence Limits
Middle Atlantic	Burn (kg)	33	104	4516	453	-640 to 849
	Time (mins)		2.9	96.7	9.8	-13.2 to 19.1
	Ratio		.0033	.0500	.0071	-.0084 to .0149
	Air Mi (nm)		1	60	8	-12 to 14
	Grnd Mi (nm)		-11	959	31	-62 to 40
Caribbean	Burn	66	-144	8508	621	-1167 to 877
	Time		-1.1	83.9	9.2	-16.1 to 14.0
	Ratio		.0001	.0013	.0011	-.0018 to .0020
	Air Mi		0	4	2	-3 to 4
	Grnd Mi		0	0	0	-1 to 1

B727 AIRCRAFT

		Flights	Mean	Vari- ance	Std. Dev.	90 Percent Confidence Limits
Caribbean	Burn	22	-87	1303	243	-486 to 314
	Time		-0.9	.0179	.0042	-.0079 to .0061
	Ratio		0	.0003	.0005	-.0009 to .0009
	Air Mi		0	0	1	-1 to 1
	Grnd Mi		0	0	0	0

MILITARY AIRCRAFT

		Flights	Mean	Vari- ance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	20	18	23691	1037	-1687 to 1724
	Time		2.7	92.9	9.6	-13.2 to 18.6
	Ratio		.0021	.0266	.0052	-.0064 to .0106
	Air Mi		5	237	15	-20 to 30
	Grnd Mi		-3	237	15	-28 to 22

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-10

TASK II RESULTS

FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 3)
WESTBOUND (Entire Flights)

B747 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn (kg)	154	243	25887	1084	-1539 to 2026
	Time (mins)		0.7	32.8	5.7	-8.7 to 10.1
	Ratio		.0072	.2625	.0162	-.0194 to .0339
	Air Mi (nm)		7	1321	36	-53 to 67
	Grnd Mi (nm)		-12	1737	42	-80 to 57
Polar	Burn	24	-79	2949	366	-681 to 522
	Time		0	3.2	1.8	-2.9 to 3
	Ratio		-.0007	.0091	.0030	-.0056 to .0043
	Air Mi		3	39	6.3	-7 to 13
	Grnd Mi		6	165	13	-15 to 27

DC10, L1011 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	65	184	23178	1025	-1503 to 1871
	Time		2.7	38.1	6.2	-7.5 to 12.8
	Ratio		.0054	.2144	.0146	-.0187 to .0295
	Air Mi		18	1532	39	-46 to 83
	Grnd Mi		-1	2746	52	-88 to 85
Caribbean	Burn	30	-5	503	151	-253 to 244
	Time		0	0.3	0.5	-0.9 to 0.9
	Ratio		.0001	.0007	.0008	-.0013 to .0015
	Air Mi		0	1	1	-1 to 1
	Grnd Mi		0	0	0	0

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	178	176	14181	802	-1144 to 1495
	Time		1.6	34.3	5.9	-8.0 to 11.2
	Ratio		.0046	.2504	.0158	-.0215 to .0306
	Air Mi		12	1454	38	-51 to 75
	Grnd Mi		0	2623	51	-85 to 84

Figure 4-10 (Continued)

B707, DC8 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Middle Atlantic	Burn (kg)	39	-91	5882	517	-941 to 759
	Time (mins)		0.5	6.3	2.5	-3.6 to 4.7
	Ratio		0	.0163	.0040	-.0067 to .0066
	Air Mi (nm)		3	114	11	-15 to 20
	Grnd Mi (nm)		4	448	21	-31 to 39
Caribbean	Burn	79	-5	1158	229	-382 to 373
	Time		0	0.9	0.9	-1.5 to 1.5
	Ratio		0	.0025	.0016	-.0026 to .0026
	Air Mi		0	2	1	-2 to 2
	Grnd Mi		0	7	3	-4 to 4

B727 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Caribbean	Burn	20	-41	884	200	-370 to 289
	Time		-0.4	3.9	2.0	-3.6 to 2.9
	Ratio		.0001	.0018	.0013	-.0021 to .0023
	Air Mi		0	3	2	-3 to 3
	Grnd Mi		0	0	0	0

MILITARY AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	28	94	1529	263	-339 to 527
	Time		0.6	17.6	4.2	-6.3 to 7.5
	Ratio		.0020	.1130	.0106	-.0155 to .0195
	Air Mi		6	526	23	-32 to 44
	Grnd Mi		-3	1042	32	-56 to 50

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-11

TASK II RESULTS

FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 3)
EASTBOUND (Flight Segments)

	NORTH ATLANTIC		POLAR		MIDDLE ATLANTIC		CARIBBEAN	
	Segments	Mean	Segments	Mean	Segments	Mean	Segments	Mean
B747 AIRCRAFT								
Burn (kg)	463	55	145	67				
Time (mins)		2		0				
DC10, L1011 AIRCRAFT								
Burn (kg)	164	65					98	0
Time (mins)		0						0
B707, DC8 AIRCRAFT								
Burn (kg)	604	33			75	27	298	19
Time (mins)		1.7				0		-0.1
B727 AIRCRAFT								
Burn (kg)							110	-12
Time (mins)								0
MILITARY AIRCRAFT								
Burn (kg)	51	0						
Time (mins)		0						

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-12

TASK II RESULTS

FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 3)
WESTBOUND (Flight Segments)

	NORTH ATLANTIC		POLAR		MIDDLE ATLANTIC		CARIBBEAN	
	Segments	Mean	Segments	Mean	Segments	Mean	Segments	Mean
B747 AIRCRAFT								
Burn (kg)	284	40	69	-120				
Time (mins)		0		-0.1				
DC10, L1011 AIRCRAFT								
Burn (kg)	118	-149					107	33
Time (mins)		0						0
B707, DC8 AIRCRAFT								
Burn (kg)	437	-45			108	-17	306	40
Time (mins)		0				0		0
B727 AIRCRAFT								
Burn (kg)							66	-8
Time (mins)								0
MILITARY AIRCRAFT								
Burn (kg)	49	0						
Time (mins)		0						

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-9 presents the findings by aircraft type group and region for the 586 eastbound flights. Average fuel burn differences ranged from -144 kg for B707/DC8 flights in the Caribbean to 350 kg for DC10/L1011 North Atlantic flights. Time differences ranged from -1.1 minutes for B707/DC8 aircraft in the Caribbean to 2.9 minutes for North Atlantic B707/DC8 flights.

Except for B707/DC8 and B727 flights in the Caribbean, average time and burn differences were all positive, along with air distance differences which were positive albeit small. This means that the time, burn and air distances are greater for the flight tracking data that were based on the forecast flight plans. Since the same weather data were used for both sets of flight tracking the apparent advantage results from the more advantageous selection of route on the new ATC tracks or the improved weather.

Figure 4-10 presents the corresponding westbound findings for Case 3. Again with few exceptions all aircraft type groups and regions showed positive differences for fuel burn and time. Therefore, for westbound flights as well as for eastbound these data imply that the fuel burn and time penalties imposed by the ATC system are less when the route selection and flight planning are accomplished on a more accurate weather forecast.

Note that for both the westbound and eastbound comparisons the differences in the Caribbean region are all either zero or very small relative to the other regions. This further confirms the above comment that the savings shown in Case 3 are primarily the result of an improved ATC track lay-out and selection. Since the Caribbean flights are less likely to be affected by the ATC tracks and since the same weather data are used the differences are negligible.

4.4 FLIGHT PLANS AND FLIGHT TRACKING ON THE VERIFYING ANALYSIS

Case 4 compared flight plans developed on the verifying analysis to flight tracking data developed on the same weather set.

This comparison was similar to Case 1 in that flight plans are compared to the corresponding flight tracking data. Here, however, both are on the same weather data whereas in Case 1 the flight plans were on the forecast and the flight tracking data were on the verifying analysis.

Since the same weather data are being used the differences found between these two groups of plans should be unrelated to weather but should measure the potential effect of improved ATC track selection and of the conflict resolution simulations of the flight tracking model.

Figure 4-13 summarizes the findings for the 586 eastbound flights. The average fuel burn differences by aircraft type and region range from -204 kg for B707/DC8 aircraft on the North Atlantic to -1034 kg for B747s on

Figure 4-13

TASK II RESULTS

FLIGHT PLANS AND FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 4)
EASTBOUND (Entire Flights)

B747 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn (kg)	160	-927	22701	1015	-2597 to 742
	Time (mins)		-1.0	9.6	3.1	-6.1 to 4.1
	Ratio		-.0009	.0092	.0030	-.0059 to .0041
	Air Mi (nm)		-10	604	25	-50 to 31
	Grnd Mi (nm)		-8	652	26	-50 to 34
Polar	Burn	33	-1034	30266	1172	-2961 to 894
	Time		0	1.8	1.3	-2.2 to 2.2
	Ratio		-.0005	.0022	.0015	-.0029 to .0019
	Air Mi		-2	48	7	-14 to 9
	Grnd Mi		0	0	0	0

DC10, L1011 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	53	-236	2716	351	-814 to 341
	Time		-0.8	6.2	2.5	-5.0 to 3.3
	Ratio		.0001	.0118	.0034	-.0056 to .0057
	Air Mi		-6	301	17	-34 to 23
	Grnd Mi		-6	271	16	-33 to 21
Caribbean	Burn	27	-471	12389	750	-1704 to 763
	Time		-0.7	31.4	5.6	-10.0 to 8.4
	Ratio		-.0003	.0093	.0031	-.0053 to .0047
	Air Mi		0	23	5	-8 to 7
	Grnd Mi		0	0	0	0

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	175	-204	3201	381	-830 to 423
	Time		-0.2	10.3	3.2	-5.5 to 5.1
	Ratio		.0001	.0073	.0027	-.0044 to .0045
	Air Mi		-2	158	13	-22 to 19
	Grnd Mi		-2	110	11	-19 to 15

Figure 4-13 (Continued)

B707, DC8 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Middle Atlantic	Burn (kg)	31	-326	4202	436	-1044 to 392
	Time (mins)		0.8	1.4	1.2	-1.2 to 2.8
	Ratio		-.0005	.0026	.0016	-.0031 to .0022
	Air Mi (nm)		-3	32	6	-12 to 7
	Grnd Mi (nm)		-1	10	3	-6 to 5
Caribbean	Burn	66	-364	11259	715	-1540 to 811
	Time		-2.6	93.3	9.7	-18.5 to 13.3
	Ratio		.0001	.0017	.0013	-.0020 to .0023
	Air Mi		0	5	2	-4 to 4
	Grnd Mi		0	0	0	0

B727 AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
Caribbean	Burn	22	-221	3202	381	-848 to 407
	Time		-2.7	43.2	6.6	-13.5 to 8.1
	Ratio		-.0002	.0004	.0007	-.0013 to .0009
	Air Mi		0	1	1	-2 to 1
	Grnd Mi		0	0	0	0

MILITARY AIRCRAFT

		Flights	Mean	Vari-ance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	19	-220	11053	708	-1385 to 945
	Time		-0.6	2.0	1.4	-2.9 to 1.8
	Ratio		-.0005	.0092	.0030	-.0055 to .0045
	Air Mi		-2	85	9	-18 to 13
	Grnd Mi		-1	31	6	-10 to 8

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Polar flights. Flight time differences were all negative and ranged up to -2.7 minutes. Air distance differences were also negative.

Since the same weather data are used in both cases, one cannot relate these differences to forecast errors. Just as in Case 1, the differences must be the result of some feature in the flight tracking simulation program. The results imply that actual flight times, fuel burns and air miles would always be higher than planned even though all flights were planned on NAT tracks that were developed from a presumably enhanced weather forecast. This suggests that the time and burn differences shown here must be attributed to the conflict resolution capabilities of the flight tracking system and as such represent the penalties incurred from traffic congestion and the ATC system regardless of the accuracy of the weather forecast.

Figure 4-14 presents the corresponding results for the 616 westbound flights included in this case. Again the average fuel burn differences for each aircraft type and region were negative ranging from -76 kg to -599 kg. Time differences ranged from -2.7 minutes to 0.4 minutes.

These data again suggest that on the average a fuel penalty in the amounts shown results from traffic congestion and ATC system conflict resolutions regardless of the weather.

Case 4 results by segments are presented in Figures 4-15 and 4-16.

Figure 4-14

TASK II RESULTS

FLIGHT PLANS AND FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 4)
WESTBOUND (Entire Flights)

B747 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn (kg)	154	-599	18597	919	-2110 to 912
	Time (mins)		0.1	19.9	4.5	-7.3 to 7.4
	Ratio		.0028	58.3	7.6	-9.8 to 15.4
	Air Mi (nm)		2	833	29	-46 to 49
	Grnd Mi (nm)		-7	705	27	-50 to 37
Polar	Burn	24	-76	5802	513	-920 to 769
	Time		-0.6	9.0	3.0	-5.6 to 4.3
	Ratio		.0003	.0014	.0012	-.0016 to .0022
	Air Mi		1	27	5	-7 to 10
	Grnd Mi		0	0	0	0

DC10, L1011 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	66	-409	17467	890	-1873 to 1055
	Time		0.4	12.7	3.6	-5.5 to 6.3
	Ratio		.0013	.0259	.0051	-.0071 to .0097
	Air Mi		0	618	25	-41 to 41
	Grnd Mi		-4	565	24	-43 to 35
Caribbean	Burn	29	-319	5118	482	-1112 to 474
	Time		0.4	2.2	1.5	-2.1 to 2.8
	Ratio		.0001	.0026	.0016	-.0026 to .0028
	Air Mi		0	8	3	-5 to 5
	Grnd Mi		0	0	0	0

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	179	-193	4163	435	-908 to 522
	Time		0	12.9	3.6	-5.9 to 5.9
	Ratio		.0004	.0168	.0041	-.0064 to .0071
	Air Mi		-2	419	20	-35 to 32
	Grnd Mi		-2	267	16	-29 to 25

Figure 4-14 (Continued)

B707, DC8 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
Middle Atlantic	Burn (kg)	38	-294	8914	636	-1340 to 752
	Time (mins)		-1.2	31.2	5.6	-10.4 to 7.9
	Ratio		-.0004	.0024	.0015	-.0030 to .0021
	Air Mi (nm)		-2	28	5	-10 to 7
	Grnd Mi (nm)		0	0	0	0
Caribbean	Burn	79	-235	4746	464	-999 to 528
	Time		0.2	9.7	3.1	-4.9 to 5.3
	Ratio		-.0003	.0036	.0019	-.0035 to .0028
	Air Mi		-1	8	3	-5 to 4
	Grnd Mi		0	0	0	0

B727 AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
Caribbean	Burn	20	-288	2297	323	-819 to 243
	Time		-1.9	35.5	6.0	-11.7 to 8.0
	Ratio		-.0007	.0055	.0023	-.0046 to .0032
	Air Mi		-1	10	3	-6 to 4
	Grnd Mi		0	0	0	0

MILITARY AIRCRAFT

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
North Atlantic	Burn	27	-79	819	193	-396 to 238
	Time		-2.7	8.6	2.9	-7.5 to 2.2
	Ratio		-.0025	.0224	.0047	-.0103 to .0053
	Air Mi		-7	252	16	-33 to 19
	Grnd Mi		0	0	0	0

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-15

TASK II RESULTS

FLIGHT PLANS AND FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 4)
EASTBOUND (Flight Segments)

	NORTH ATLANTIC		POLAR		MIDDLE ATLANTIC		CARIBBEAN	
	Segments	Mean	Segments	Mean	Segments	Mean	Segments	Mean
B747 AIRCRAFT								
Burn (kg)	1022	-36	218	-53				
Time (mins)		0		0				
DC10, L1011 AIRCRAFT								
Burn (kg)	356	-6					106	5
Time (mins)		0						0
B707, DC8 AIRCRAFT								
Burn (kg)	1347	-9			136	-21	327	-2
Time (mins)		0				0		0
B727 AIRCRAFT								
Burn (kg)							123	-3
Time (mins)								0
MILITARY AIRCRAFT								
Burn (kg)	115	3						
Time (mins)		0						

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-16

TASK II RESULTS

FLIGHT PLANS AND FLIGHT TRACKING ON THE VERIFYING ANALYSIS (CASE 4)
WESTBOUND (Flight Segments)

	NORTH ATLANTIC		POLAR		MIDDLE ATLANTIC		CARIBBEAN	
	Segments	Mean	Segments	Mean	Segments	Mean	Segments	Mean
B747 AIRCRAFT								
Burn (kg)	908	-10	137	-4				
Time (mins)		0		-0.1				
DC10, L1011 AIRCRAFT								
Burn (kg)	394	0					124	-10
Time (mins)		0						-0.1
B707, DC8 AIRCRAFT								
Burn (kg)	1247	-3			159	-32	351	-17
Time (mins)		0				-0.4		-0.1
B727 AIRCRAFT								
Burn (kg)							98	-15
Time (mins)								-0.4
MILITARY AIRCRAFT								
Burn (kg)	187	-2						
Time (mins)		0						

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

4.5 ACTUAL AIRLINE FLIGHT PLANS AND FLIGHT TRACKING FLIGHT PLANS

The final case of Task II compared actual airline flight plans based on forecast weather, from Task III, to the corresponding flight plans developed from the SRI flight tracking model on both the forecast weather and the verifying analysis.

The results of these comparisons are presented in Figures 4-17 and 4-18. Since takeoff weights, flight levels and routings in the airline plans were quite different from those produced by the flight tracking model the differences were enormous. Average fuel burn differences were over 10,000 kg when the forecast weather was used, and differences of 10,700 kg eastbound and 7100 kg westbound were found on the plans based on the verifying analysis. As a result, these data were judged to be not meaningful.

Figure 4-17

TASK II RESULTS

ACTUAL AIRLINE FLIGHT PLANS AND SRI FLIGHT PLANS ON FORECASTS (CASE 5)

Entire Flights

		Flights	Mean	Variance	Std. Dev.	90 Percent Confidence Limits
Eastbound	Burn (kg)	17	10382	92286	6471	-262 to 21027
	Time (mins)		-3.2	207.8	14.4	-26.9 to 20.5
	Ratio		-.0129	.1446	.0120	-.0327 to .0069
	Air Mi (nm)		14	3267	57	-80 to 108
	Grnd Mi (nm)		56	1249	35	-3 to 114
Westbound	Burn	30	10026	395655	13398	-12015 to 32066
	Time		6.5	348.8	18.7	-24.2 to 37.2
	Ratio		.0061	.4590	.0214	-.0291 to .0413
	Air Mi		60	3020	55	-30 to 150
	Grnd Mi		43	3657	60	-57 to 142

Flight Segments

	Segments	Mean Burn	Mean Time
Eastbound	2	-272	-1
Westbound	28	-212	0.8

NOTE: All flights in this comparison were North Atlantic and with B747 equipment.

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.

Figure 4-18

TASK II RESULTS

ACTUAL AIRLINE FLIGHT PLANS AND SRI FLIGHT PLANS ON ACTUAL WEATHER (CASE 5)

Entire Flights

		Flights	Mean	Vari- ance	Std. Dev.	90 Percent Confidence Limits
Eastbound	Burn (kg)	17	10702	95391	6579	-120 to 21525
	Time (mins)		-1.2	256.6	16.0	-27.5 to 25.2
	Ratio		-.0088	.2654	.0163	-.0356 to .0180
	Air Mi (nm)		24	4476	67	-86 to 134
	Grnd Mi (nm)		50	1264	36	-9 to 108
Westbound	Burn	16	7126	624467	16833	-20564 to 34816
	Time		8.4	405.5	20.1	-24.7 to 41.6
	Ratio		.0042	.4267	.0207	-.0298 to .0382
	Air Mi		50	5021	71	-67 to 166
	Grnd Mi		50	2666	52	-34 to 135

Flight Segments

	Segments	Mean Burn	Mean Time
Eastbound	4	-159	-0.3
Westbound	3	771	1.3

Source: PRC Speas Analysis of Flight Planning and Flight Tracking Data.